

AFA3D MANUAL

v 1.1

AFA3D (Anthropological Facial Approximation in 3D) is a module integrated to TIVMI software (developed by B. Dutailly, UMR 5199 PACEA), that allows for the approximation of the face from craniometric data. The estimation method has been created during a PhD degree (Guyomarc'h 2011)¹, at the Université de Bordeaux 1, UMR 5199 PACEA – A3P (<http://www.pacea.u-bordeaux1.fr/>). The estimation process has been coded in R by F. Santos (UMR 5199 PACEA), and the warping algorithm has been written by J. Charton (UMR 5800 LaBRI, <http://www.labri.fr/>), and the general integration in TIVMI was performed by B. Dutailly.

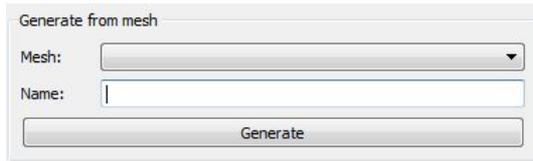
The 3D coordinates of 78 landmarks are necessary for the processing of a facial approximation. If some of them are missing on the target skull, the user has to estimate their position prior to the use of AFA3D.

This manual defines the way to position those 78 landmarks, and describes the different steps to obtain an approximated face.

The 3D skull surface

- If a CT-scan of the target skull is available, TIVMI can reconstruct the surface with an optimal reliability using the **HMH 3D** algorithm (see **TIVMI manual** for instructions).
- A surface obtained by **laser scanning** (NextEngine, Breuckmann, etc.) or photogrammetry 3D can also be imported in different format in TIVMI (.ply, .pts, .obj, .stl).
- Another option is to record the landmarks on the skull using a digitizer (Microscribe, Polhemus, etc.), and import the list of landmarks in TIVMI (see at the end of this manual for the **specific file format required**).

¹ P. Guyomarc'h (2011), Reconstitution faciale par imagerie 3D: Variabilité morphométrique et mise en œuvre informatique, UMR 5199 PACEA, Anthropologie des Populations Passées et Présentes, Université Bordeaux 1 (in French, download at: <http://www.theses.fr/2011BOR14354>).



If dealing with a 3D skull surface, the landmarks will be positioned directly in AFA3D, following a check list. Once displayed in TIVMI, the mesh must be imported in the module : in the AFA3D window, select the target mesh, name it for the approximation, and click on "**Generate**".

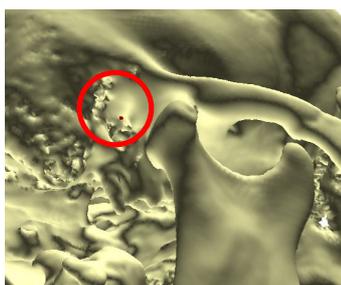
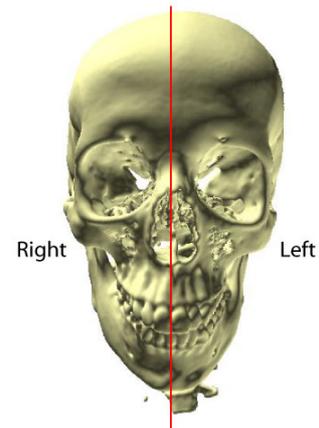
The original mesh can be hidden, or erased if no longer needed. Show the new surface, created especially for AFA3D, using the eye symbol in the object tree. The color of the skull can be changed in the AFA3D bottom window (Display box).



Name	Status
Porion (right)	✗
Porion (left)	✗
Orbitale (right)	✗
Orbitale (left)	✗
Nasion	✗
Glabella	✗

The 78 landmarks can now be positioned. A checklist indicates the name of the landmark and the status (placed or not). The skull must be oriented correctly to spot the point, and then click on the name of the landmark to select it, before clicking on the landmark position on the skull. The placed landmark can be repositioned by clicking another time on its name.

Right and left landmarks must be placed anatomically: the right side is at the left of the screen when facing the skull. If the surface has been reconstructed from DICOM files, the skull might need to be mirrored to respect the anatomical lateralization.



1) Porion

The most superior point of the external acoustic meatus can be spotted in lateral view, and placed in inferior view. (right porion depicted)



2) Orbitale

The most inferior point of the orbital margin must be placed in superior view, after locating the most inferior region of the margin in anterior view. (right orbitale depicted)





3) Nasion

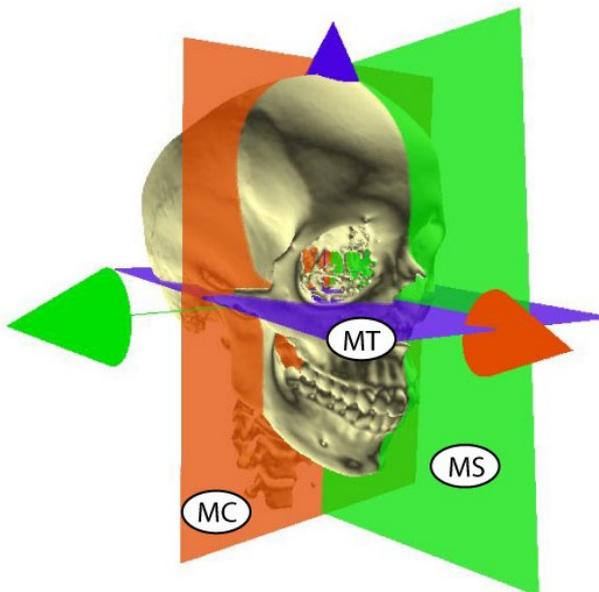
This point is at the intersection of the naso-frontal and inter-nasal sutures. If the inter-nasal suture is not clear, place the nasion at the center of the naso-frontal suture.

Construction of planes

Once the previous 5 landmarks are positioned, the reference planes must be computed. This step is necessary to help the positioning of several landmarks and further to project the estimated soft tissue depths. Click on "**Compute planes**".

Compute planes		Import bone landmarks	
Name	Status		
Porion (right)	✓		
Porion (left)	✓		
Orbitale (right)	✓		
Orbitale (left)	✓		
Nasion	✓		
Glabella	✗		

The resulting planes are displayed. They can be manipulated with the "**Plan**" window in TIVMI. The following figure displays the planes and their **normal** (that can be showed by selecting each plane and checking the "**show normal**" box). By default, MT is oriented superiorly, MC anteriorly and MS towards the left side of the screen (anatomical right). This orientation of the perpendiculars will have to be exactly the same at the end of the 78 landmarks positioning (but can be changed during the positioning phase).



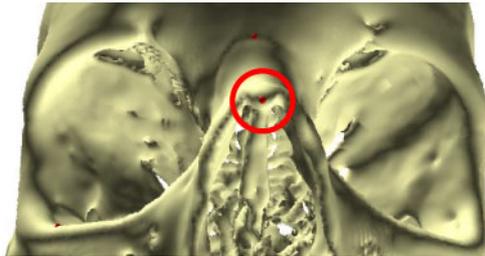
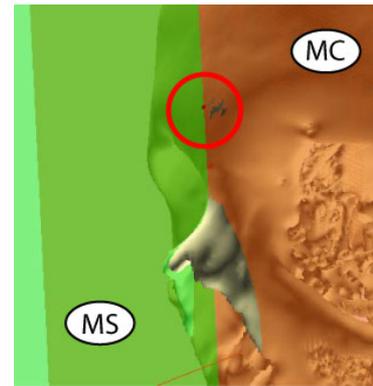
MT = Mean transverse, homologous to the **Frankfurt Horizontal**.

MC = Mean coronal (or frontal) plane.

MS = Mean sagittal plane.

4) Glabella

The midline point most anterior between the superciliary archs can be placed using the MC plane. MC can be shifted anteriorly until delimiting the most anterior zone; the glabella must be placed on the MS plane to ensure its midline position.

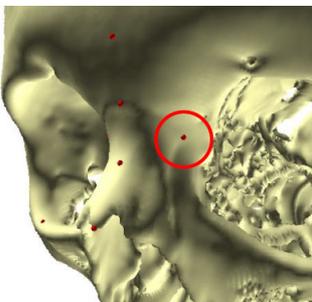
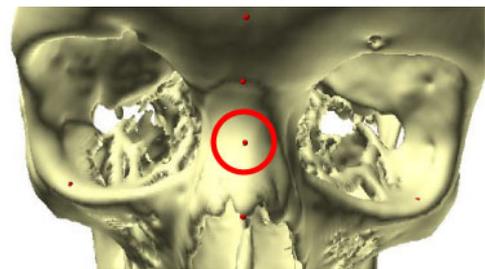


5) Rhinion

The most inferior point of the inter-nasal suture can be placed in inferior view.

6) Mid-nasal

This point is between the nasion and the rhinion, on the inter-nasal suture, placed in superior view.

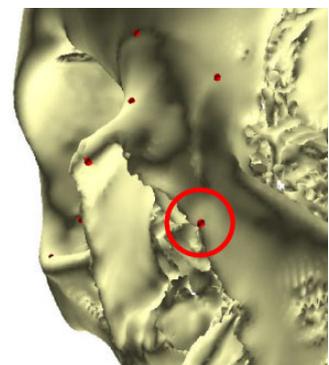


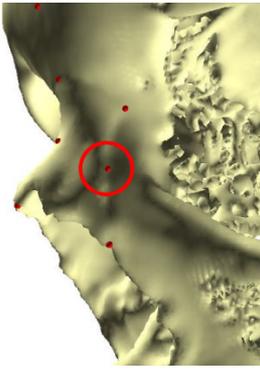
7) Nasomaxillofrontale

This point is at the intersection of the sutures between the frontal, nasal and maxillary bones. (left nasomaxillofrontale depicted)

8) Nasomaxillare

This is the most inferior point on the naso-maxillary suture, placed on the nasal aperture. (left nasomaxillare depicted)



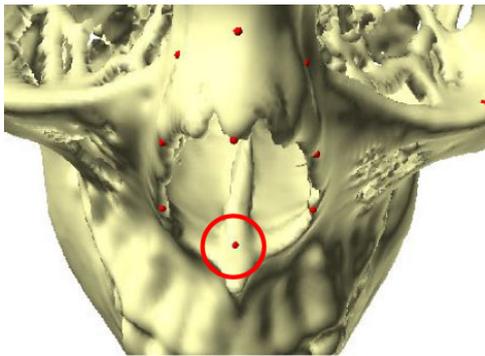
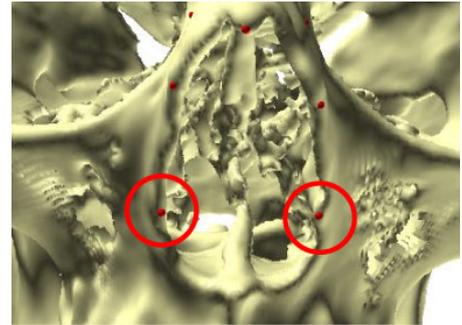


9) Mid-nasomaxillare

This point is placed on the naso-maxillary suture, between the nasomaxillofrontale and the nasomaxillare. (left mid-nasomaxillare depicted)

10) Apertion

The most lateral points of the nasal aperture may be placed in anterior view. (both right and left apertion depicted)

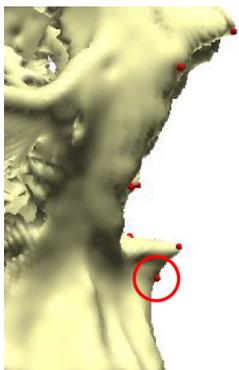
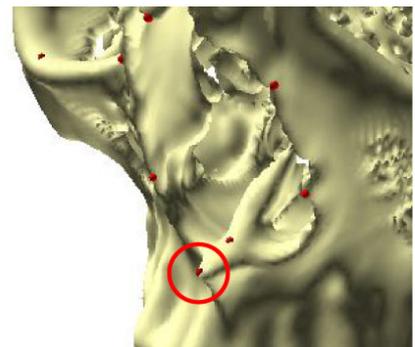


11) Nasospinale superior

This is the midline point on the inter-maxillary suture and on the lower nasal aperture. It can be placed on superior view, in line with the nasal spine.

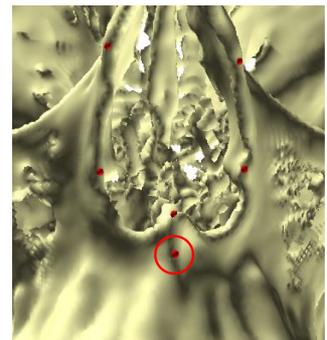
12) Spinale

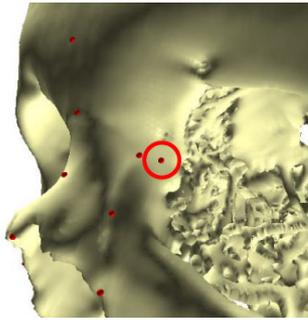
This is the most anterior point of the nasal spine that can be placed in anterior view.



13) Sub-spinale

This point is at the maximum of curvature below the nasal spine. It can be spotted in lateral view, and its position can be corrected in anterior view in order to be on the midline.



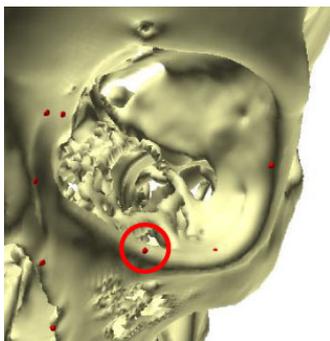
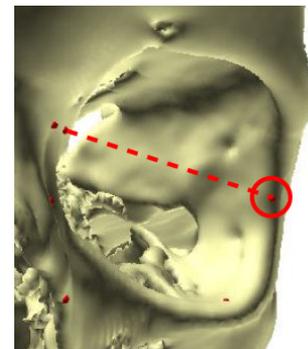


14) Maxillofrontale

This point is at the intersection of the lacrymal, frontal and maxillary sutures. Those structures are relatively thin, and are hardly visible on CT-scan reconstructions. It must be placed on the medial orbital margin, in order to define the orbital breadth with the ectoconchion. (left maxillofrontale depicted)

15) Ectoconchion

This is the most lateral point of the orbital margin, but not strictly. It defines a line bisecting the orbit (parallel to the superior and inferior margins) with the maxillofrontale. It is placed in anterior view. (left ectoconchion depicted)

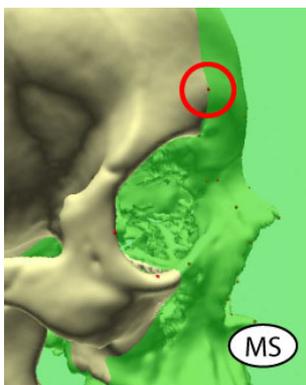
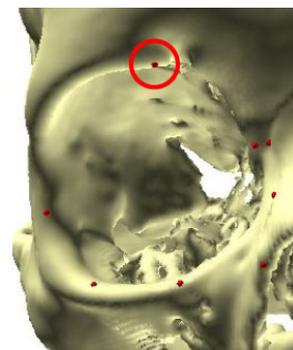


16) Zygoorbitale

This point is on the inferior orbital margin, on the zygo-maxillary suture, placed on superior view.

17) Supraconchion

This is the most superior point of the orbital margin, spotted in anterior view, and placed in inferior view. If a supraorbital notch is present, the supraconchion must not be placed inside, but on its periphery on the orbital margin.



18) Superciliare

This point is approximately on a midline bisecting the orbit vertically, on the most prominent part of the supraorbital ridge. The MS can be shifted at the center of the orbit in anterior view, and a rotation of the skull laterally allows for the visualization of the most anterior region. If the frontal bone is not convex enough, the superciliare must still be placed 1 or 2 cm above the orbital margin. This lack of precision is not important, as this point only defines a soft tissue thickness. (right superciliare depicted)

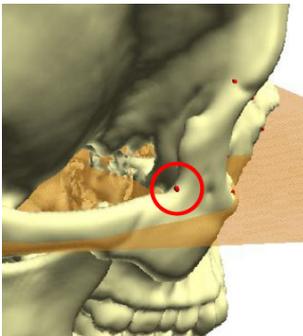
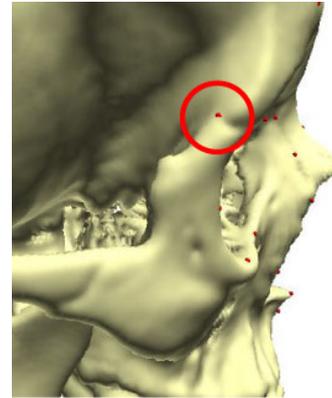


19) **Frontomalare orbitale**

This point is on the lateral orbital margin, on the fronto-zygomatic suture. (right frontomalare orbitale depicted)

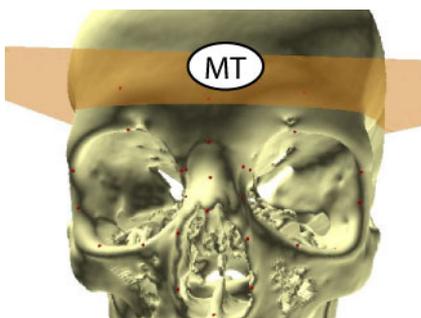
20) **Frontomalare temporale**

This point is on the most posterior part of the fronto-zygomatic suture. (right frontomalare temporale depicted)



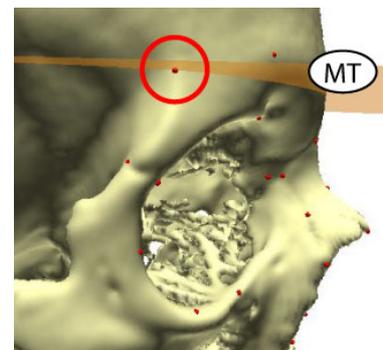
21) **Jugale**

This point is the most anterior and inferior of the posterior part of the zygomatic bone. (right jugale depicted)



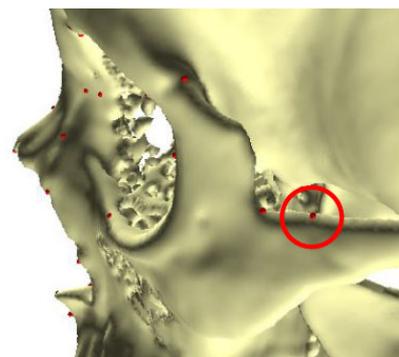
22) **Frontotemporale**

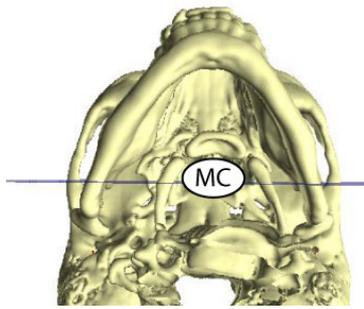
This point is the most anterior on the temporal line of the frontal bone, but it also defines the minimal frontal breadth. The MT can be shifted in anterior view until defining this breadth, and the point can be placed on the temporal line in lateral view. (right frontotemporale depicted)



23) **Zygotemporale superior**

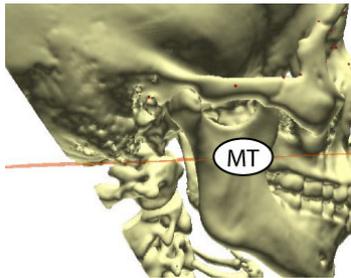
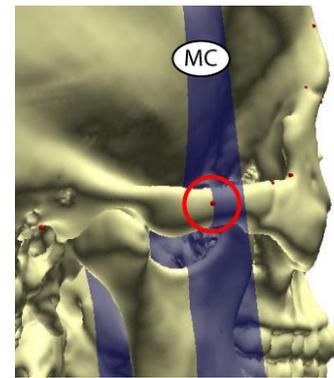
This point is the most superior one on the zygo-temporal suture. (left zygotemporale superior depicted)





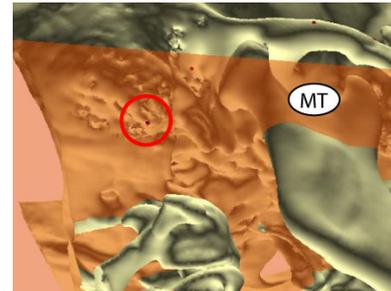
24) Zygion

This point is the most lateral point of the zygomatic arch, and defines the bizygomatic breadth. The MC can be shifted in inferior view until spotting this breadth, and the zygion placed in lateral view. (right zygion depicted)



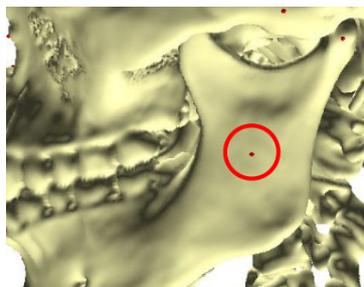
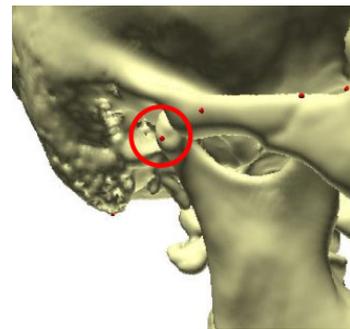
25) Mastoidale

This is the most inferior point of the mastoid process, that can be spotted by shifting the MT plane in inferior view. (right mastoidale depicted)



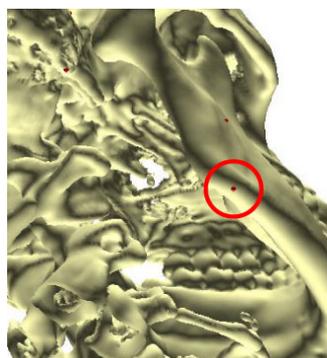
26) Condylion

This is the most lateral point of the condylar process on the mandible, that can be position on a lateral view. (right condylion depicted)



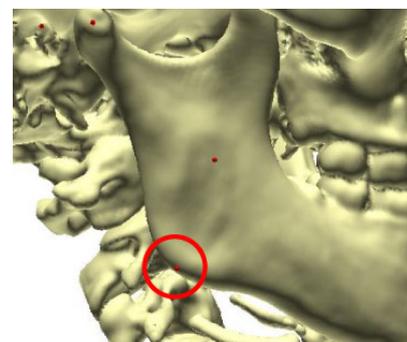
27) Midramus

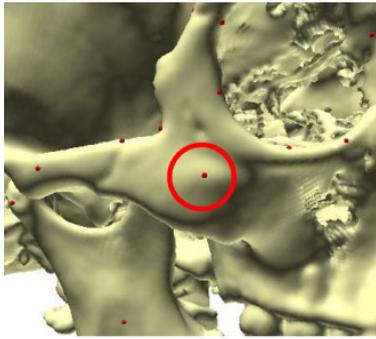
This point is at the center of the mandibular branch, placed in lateral view. (left midramus depicted)



28) Gonion

This is the most posterior and inferior point of the mandibular branch, at the maximum of curvature of the goniac angle. It can be spotted on lateral view and positioned in posterior view. (right gonion depicted)



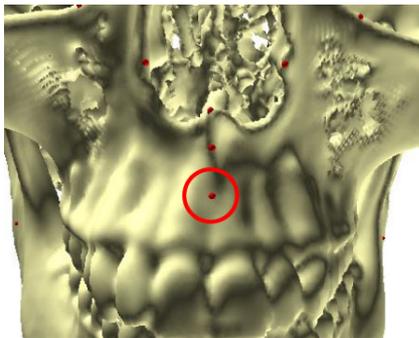
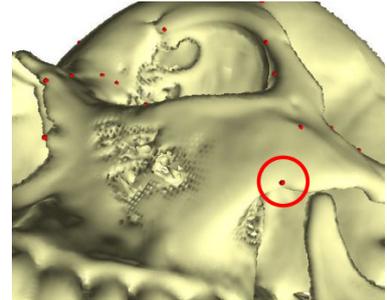


29) Zygomatic

This is the most salient point of the zygomatic, on the insertion of the muscle zygomatic major, placed in antero-lateral view. (right zygomatic depicted)

30) Zygomaxillare

This is the most inferior point on the zygo-maxillary suture, placed in inferior view. (left zygomaxillare depicted)

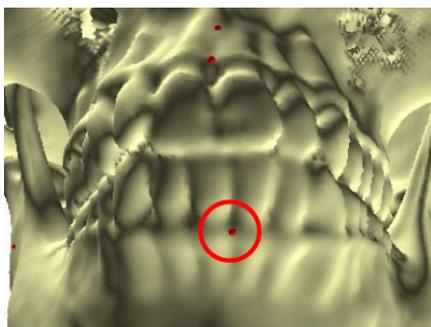
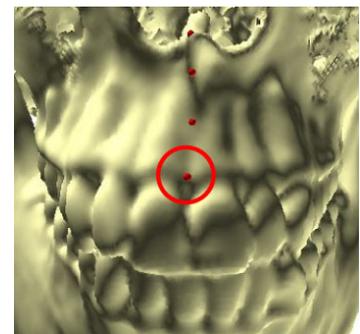


31) Midphiltrum

This midline point is at the center of the alveolar process on the inter-maxillary suture, between the sub-spinale and the prosthion.

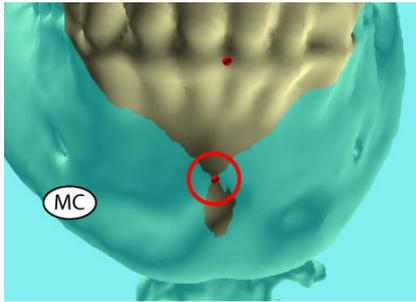
32) Prosthion

This midline point is the most infero-anterior on the maxillary alveolar process, between the central incisors. It must be placed, even in edentulous subjects.



33) Infradentale

This midline point is the most supero-anterior point on the mandible alveolar process, between the central incisors. It must be placed, even in edentulous subjects.

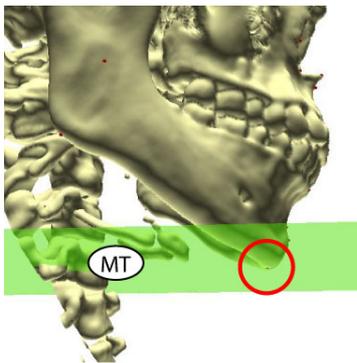
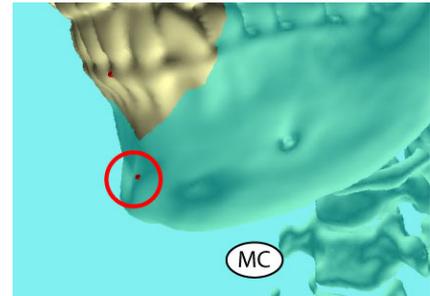


34) **Labiomentale**

This midline point is at the maximum of curvature of the labiomentale sulcus, it can be spotted by shifting anteriorly the MC plane, in anterior view.

35) **Pogonion**

This midline point is the most anterior point of the mental eminence, when the mandible is in occlusion.

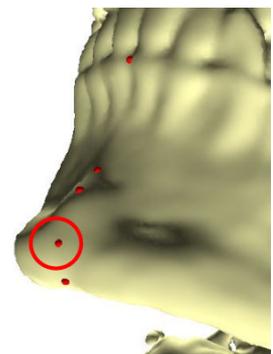


36) **Gnathion**

This midline point is the most inferior of the chin, it can be spotted by shifting inferiorly the MT plane.

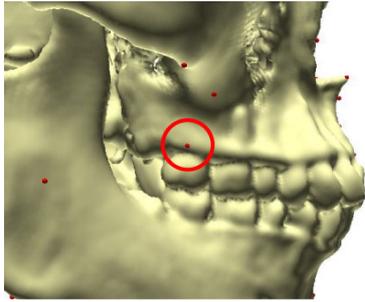
37) **Supragnathion**

This midline point is the most anterior and inferior of the chin, between the pogonion and the gnathion.



38) **Sub-maxillar curvature**

This point is the most superior and medial point of the maxillar curvature. It can be spotted in anterior view and placed in lateral view. (right sub-maxillar curvature depicted)

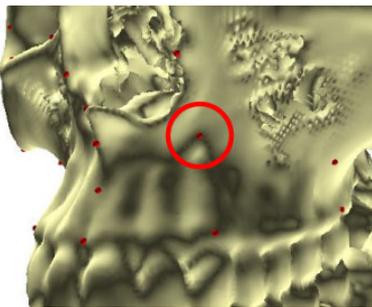
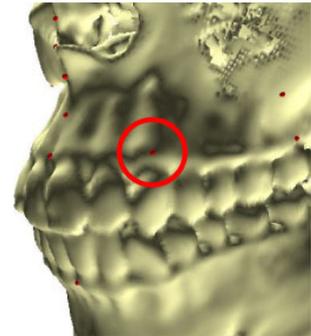


39) Ectomolare

This point is placed in lateral view, on the alveolar process above the second superior molar. (right ectomolare depicted)

40) Supracanine

This point is on the alveolar process above the superior canine, placed in antero-lateral view. (left supracanine depicted)

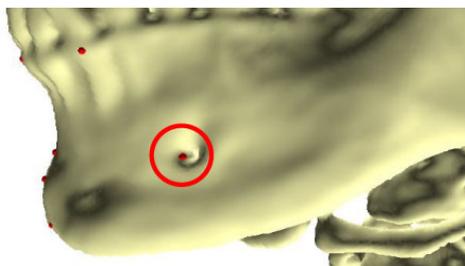
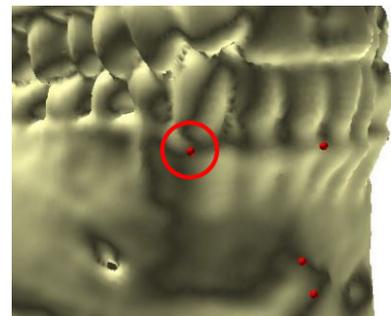


41) Canine fossa

This point is the most posterior and medial of the maxilla, in the canine fossa. (left canine fossa depicted)

42) Infracanine

This point is on the alveolar process below the inferior canine, placed in antero-lateral view. (right infracanine depicted)

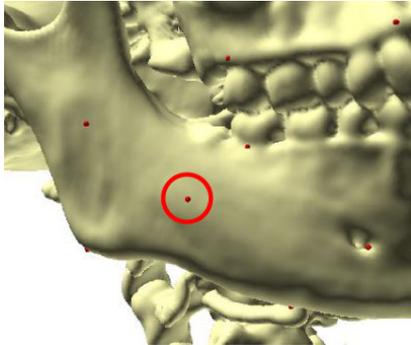
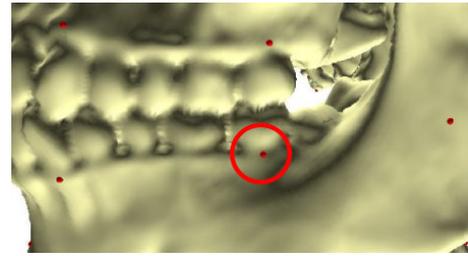


43) Mental foramen

This point is placed on the anterior part of the mental foramen, in lateral view. (left mental foramen depicted)

44) Inframolare

This point is placed in lateral view, on the alveolar process below the second inferior molar. (left inframolare depicted)

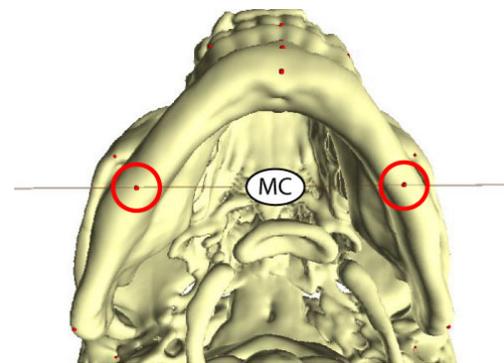


46) Midmandibular body

This point is on the center of the oblic line of the mandibular body, spotted in anterior view and placed in lateral view. (right midmandiular body depicted)

45) Midmandibular border

This point is placed in inferior view, on the mandibular border between the gonion and the gnathion. Its position can be spotted by shifting the MC plane. (both right and left midmandibular border depicted)



Estimation of the 100 skin landmarks

Check the plane normals in order to keep the MT oriented superiorly, the MS towards the left side of the screen, and the MC anteriorly (see page 3).

Target		
Sex	Age	Corpulence
<input checked="" type="radio"/> Unknown	<input checked="" type="radio"/> Unknown	<input checked="" type="radio"/> Unknown
<input type="radio"/> Male	<input type="radio"/> < 40	<input type="radio"/> Normal
<input type="radio"/> Female	<input type="radio"/> >= 40	<input type="radio"/> Overweight

If known, you can select the **sex** (Male / Female), **age** (Inferior / superior to 40 years) and **corpulence** (Normal / Overweight, respectively less or more than 25 kg/m²) of the subject. Leave unknown to produce an average of the corresponding factor.

Once the factors checked, and if all the landmark statuses are green, click on "**Compute skin landmarks**" to process the estimation.

Compute skin landmarks

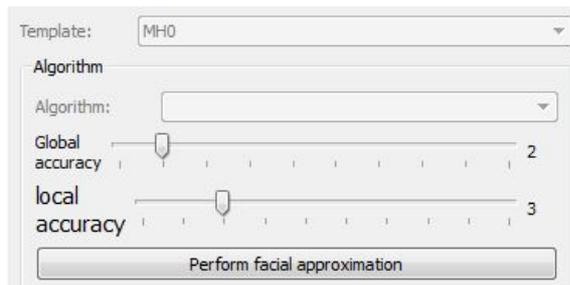
Soft tissue depths are estimated using regression formulae, and landmarks of **facial organs** (eyes, nose, mouth and ears) are independently estimated with regressions of PC scores extracted after **Procrustes superimpositions** of the datasets in **R** (<http://www.r-project.org/>). Consult the dissertation Guyomarc'h (2011) for more information.

The **100 skin landmarks** are kept in memory, the warping can be performed.

Warping of the synthetic face

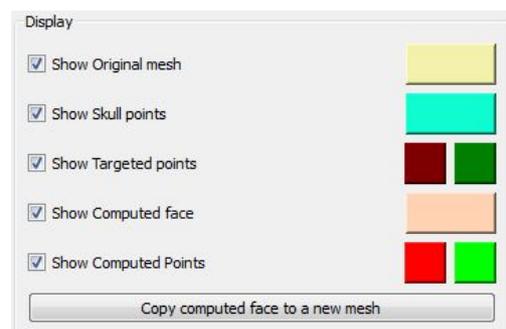
The only template available for the warping, is the basic **synthetic face** extracted from the MakeHuman software. This neutral face was constructed from several faces, and graphically enhanced by artists and engineers. See **MakeHuman** website for information on the humanoid mesh (<http://www.makehuman.org/> ; <http://sites.google.com/site/makehumandocs/the-humanoid-mesh>).

The algorithm used (developed by J. Charton, UMR 5800) is described in annex of Guyomarc'h (2011).



Global accuracy (first warping) and **local accuracy** (second warping only at the landmarks of facial organs) can be changed to enhance the precision of the approximation. A global accuracy of 2 (0,01 mm) and a local accuracy of 3 (0,001 mm) are advised to obtain a correct visual. Setting a higher accuracy will take more time for the warping to process, and may not necessarily result in a better approximation.

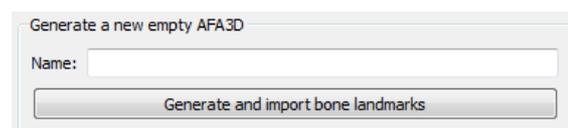
Click "**Perform facial approximation**" to process the warping. Once the warping is done, the computed face can be displayed with commands in the AFA3D window.



User should finally click on "**Copy computed face to a new mesh**" to export the approximation in the mesh category. This mesh can be saved, and exported in different file format, readable by most 3D graphic software.

Texturing and modification of the face cannot be performed in AFA3D. Further developments will be posted at <http://www.pacea.u-bordeaux1.fr/TIVMI/>

File format for import bone landmarks



The file must be a text file (*.txt) with 78 lines corresponding to the 78 landmarks in a specific order. 3D coordinates must be separated with a single space, and a point (.) for the decimal (no comma). No text is supported (do not put the landmark's name before the coordinates or the subject denomination).

Example:

X1 Y1 Z1
 X2 Y2 Z2
 X... Y... Z...
 X78 Y78 Z78

Order:

- | | |
|------------------------------------|------------------------------------|
| 1) Porion (left) | 47) Condylion (right) |
| 2) Porion (right) | 48) Midramus (right) |
| 3) Orbitale (left) | 49) Gonion (right) |
| 4) Orbitale (right) | 50) Zygomatic (left) |
| 5) Nasion | 51) Zygomaxillare (left) |
| 6) Glabella | 52) Zygomatic (right) |
| 7) Rhinion | 53) Zygomaxillare (right) |
| 8) Mid-nasal | 54) Midphiltrum |
| 9) Nasomaxillofrontale (left) | 55) Prosthion |
| 10) Nasomaxillare (left) | 56) Infradentale |
| 11) Mid-nasomaxillare (left) | 57) Labiomentale |
| 12) Apertion (left) | 58) Pogonion |
| 13) Nasomaxillofrontale (right) | 59) Gnathion |
| 14) Nasomaxillare (right) | 60) Supragnathion |
| 15) Mid-nasomaxillare (right) | 61) Sub-maxillar curvature (left) |
| 16) Apertion (right) | 62) Ectomolare (left) |
| 17) Nasospinale superior | 63) Supracanine (left) |
| 18) Spinale | 64) Canine fossa (left) |
| 19) Sub-spinale | 65) Infracanine (left) |
| 20) Maxillofrontale (left) | 66) Mental foramen (left) |
| 21) Ectoconchion (left) | 67) Inframolare (left) |
| 22) Zygoorbitale (left) | 68) Midmandibular body (left) |
| 23) Supraconchion (left) | 69) Sub-maxillar curvature (right) |
| 24) Superciliare (left) | 70) Ectomolare (right) |
| 25) Frontomalare orbitale (left) | 71) Supracanine (right) |
| 26) Frontomalare temporale (left) | 72) Canine fossa (right) |
| 27) Jugale (left) | 73) Infracanine (right) |
| 28) Zygotemporale superior (left) | 74) Mental foramen (right) |
| 29) Maxillofrontale (right) | 75) Inframolare (right) |
| 30) Ectoconchion (right) | 76) Midmandibular body (right) |
| 31) Zygoorbitale (right) | 77) Midmandibular border (left) |
| 32) Supraconchion (right) | 78) Midmandibular border (right) |
| 33) Superciliare (right) | |
| 34) Frontomalare orbitale (right) | |
| 35) Frontomalare temporale (right) | |
| 36) Jugale (right) | |
| 37) Zygotemporale superior (right) | |
| 38) Frontotemporale (left) | |
| 39) Frontotemporale (right) | |
| 40) Zygion (left) | |
| 41) Zygion (right) | |
| 42) Mastoidale (left) | |
| 43) Mastoidale (right) | |
| 44) Condylion (left) | |
| 45) Midramus (left) | |
| 46) Gonion (left) | |

CONTACT:

For any question about AFA3D: installation, citation, methodology, feedback appreciated!

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